Federal Geodetic Control Subcommittee

Evaluation of the Trimble 4700 GPS System

And GPSurvey V2.30 Software

November 20, 1998

Gaithersburg, Maryland

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Introduction

The Instrument Working Group (IWG) of the Federal Geodetic Control Subcommittee (FGCS) performs tests of GPS survey systems, analyzes the data, and comments on the results. The FGCS provides the technical means for evaluation of surveying systems and testing is not meant to be considered a certification process. Trimble tested the 4700 GPS system and the GPSurvey™ V2.30 postprocessing software November 15th through the 20th, 1998 in and around Gaithersburg, Maryland. Roy Anderson of the National Geodetic Survey (NGS) coordinated the test and Joe Evjen, also of the NGS, provided technical oversight. An FGCS representative was present during all observing sessions.

Field observations for the test were performed over control monuments on the grounds of the National Institute of Standards and Technology (NIST), and in the surrounding area in the states of Maryland and Virginia. In addition, data from the NGS Continuously Operating Reference Station (CORS) network were also included as a demonstration of the ability of the GPSurvey V2.30 software to process data derived from the Receiver Independent Exchange (RINEX) format and also from a variety of non-Trimble GPS receivers. The baselines formed from the network of control points have short (<1 km), medium (7-8 km), long (30-100 km) and very long (> 1000 km) lengths.

Data was collected using both static and kinematic techniques. For the static occupations, one hour observing sessions were used for short and medium length baselines and three hour sessions were used for the long and very long length baselines. During the Real-Time Kinematic (RTK) portion of the data collection, base and rover receivers were configured to record measurements for postprocessing in addition to performing the RTK survey. For short RTK baselines, two-minute stop-and-go occupations were used; for the medium and long baselines, five-minute occupations were used.

Postprocessing and network adjustments were performed with the GPSurvey software suite. Broadcast orbits were used for all the short baselines and for the postprocessed kinematic observations. International GPS Service for Geodynamics (IGS) rapid orbits were used for all long and very long static occupations. After processing, the baseline vectors were analyzed for loop closure and repeatability. Both minimally and fully constrained network adjustments were performed using FGCS coordinates for the fixed stations. The network adjusted positions of unconstrained stations in the adjustments were then compared to the FGCS coordinates.

On Friday, November 20, 1998, at a public meeting of the FGCS, Trimble presented the results of the test and delivered this paper. All field logs, solution summaries, and data files, in both RINEX and Trimble formats, were delivered to the FGCS.

Hardware and Software

The Trimble 4700 GPS receiver was used in the field to collect the GPS measurements and to perform RTK surveys. This receiver was connected to the Trimble Micro-Centered™ antenna with a groundplane (no groundplane was used for the RTK roving receiver). The GPSurvey software suite was used to process all the measurement data and to perform least squares network adjustments of the postprocessed baselines.

The Trimble 4700 GPS Receiver

Introduced in 1998, the new Trimble 4700 GPS receiver offers hardware and firmware enhancements that produce superior tracking capability, improved resistance to radio frequency (RF) signal jamming, and improved signal processing to mitigate multipath effects. With L1 and L2 signal tracking of up to 9 GPS satellites using parallel channels, it utilizes L1 C/A code, and L1/L2 full-cycle carrier phase measurements to achieve the highest quality data even during encryption. The latest Trimble dual-frequency technology includes hardware and firmware advancements that yield superior satellite signal tracking performance.

Trimble provides a performance specification for horizontal and vertical accuracy as shown in Table 1.

Table 1. 4700 Accuracy Specifications[1]

Static Survey		RTK Survey	
Horizontal	Vertical	Horizontal	Vertical
0.005 m + 1 ppm	0.010 m + 1 ppm	0.010 m + 2 ppm	0.020 m + 2 ppm

1 Assumes recommended surveying procedures and conditions are met.

Key features of the 4700 survey system

- Low Power consumption (4.5 Watts).
- Both real-time and postprocessed data collection techniques.
- Up to 120 hours of data can be stored (6 satellite L1/L2 data with 15 second logging interval).
- Modular system with separate antenna and receiver.
- Internal receive-only radio (optional) for RTK applications.
- Fully compatible with the Trimble 4800 GPS system.
- Fully compatible with Trimble TSC1™ with Trimble Survey Controller™, GPSurvey and Trimble Survey Office™.

The Micro-Centered L1/L2 Antenna

The Micro-Centered L1/L2 antenna, designed for high accuracy surveying, has a stable and nearly zero-offset phase center. The antenna achieves high accuracy and good symmetry characteristics from a dual-frequency L1/L2 four-feed patch.

The GPSurvey V2.30 Software Suite

GPSurvey V2.30a was used for all postprocessing of static and kinematic data. GPSurvey contains the Weighted Ambiguity Vector Estimation (WAVE™) processing engine and a least squares network adjustment processor, TRIMNET™ Plus. RINEX data import and export is standard in this software.

The WAVE processor has default control settings that were used for processing both long and short baselines. It provides On-the-fly (OTF) ambiguity resolution for optimal processing of continuous kinematic data. WAVE has advanced controls, for baseline processing, that provide capabilities for:

- Precise ephemeris
- Solid earth tide model
- Earth rotation parameters
- Estimation of zenith delay states for tropospheric modeling
- MSIS90 standard atmosphere model
- Ionospheric modeling
- Elevation-dependent antenna phase center modeling with phase center tables for most common CORS antennas in addition to Trimble antennas
- Residual editing
- Compatibility with the NGS data exchange formats (B and G files)

The TRIMNET Plus network adjustment software produces least squares adjustments of survey data from both GPS and classical terrestrial observations. Geoid models can be used in adjustments, and observation data can be weighted individually or placed in variance component groups. The TRIMNET Plus software also has a robust blunder detection scheme that uses a chi square test and tau test to identify poor observations. Controls in TRIMNET Plus allow the user to apply rotation and scale parameters to the observations to account for datum defects between GPS or conventionally derived data and local coordinates. Any number of stations may be held fixed while performing an adjustment.

Field Data Collection

All field data collection sessions took place over four days. Each static session is identified by the Julian day of the observation and a unique one-letter code. Kinematic session IDs are prepended with a three-letter code (PPK, postprocessed kinematic; RTK, real-time kinematic) to distinguish the postprocessed and real-time sessions. The Session IDs and observation times are listed in Table 2. During each static session, six receivers were running simultaneously, elevation masks were set to 10 degrees, and data was logged every 15 seconds. During each kinematic session, two receivers were running simultaneously, and elevation masks were set to 13 degrees (the default for RTK surveys). The roving receivers calculated real-time positions every second, and both the base and roving receivers stored measurements every 5 seconds for postprocessing.

Table 2. Observation Sessions.

Date	Session ID	Observation Time (UTC)
Sunday November 15, 1998	319A	13:00 - 14:00
	319C	16:00 – 17:00
	319E	19:00 – 20:00
Monday November 16, 1998	320A	13:00 – 16:00
Tuesday November 17, 1998	321A	13:00 – 16:00
Wednesday November 18, 1998	PPK322A PPK322B RTK322A	13:13 – 14:31 15:28 – 16:39 13:06 – 13:55

The stations occupied during the static sessions are listed in Table 3. All static occupations used fixed height tripods except ASTW where a permanent monument pier is available. Trimble L1/L2 Micro-Centered antennas were used with groundplanes.

Table 3. Static Station Occupations.

	ASTW	ATHY	CHL1	GAIT	GORF	MPT5	NBS0	NBS1	NBS3	NBS5	NC25	NLIB	ORM1	SCOL
319A		X		X			X	X	X	X			X	
319C		X		X			X	X	X	X			X	
319E		X		X			X	X	X	X			X	
320A	X		X	X	X	X				X	X	X		X
321A	X	X	X	X	X					X	X	X	X	

For the kinematic observations, one receiver was set up as a base station at station N102. The roving receiver occupied the stations shown in Table 4. The roving receiver for the RTK sessions used a Trimble L1/L2 Micro-Centered antenna without the groundplane. The roving receiver for the PPK sessions used a Trimble L1/L2 Micro-Centered antenna with groundplane.

Table 4. Kinematic Rover Station Occupations

	KINA	KINB	KINC	KIND	KINE	KINF	SURV	KINM	STAT	RAPI
PPK322A	X						X	X	X	X
PPK322B	X						X	X	X	X
RTK322A	X	X	X	X	X	X				

All stations observed during the test along with their FGCS reference coordinates are listed in Table A1 (see Appendix). The stations are mapped in Figure 1.

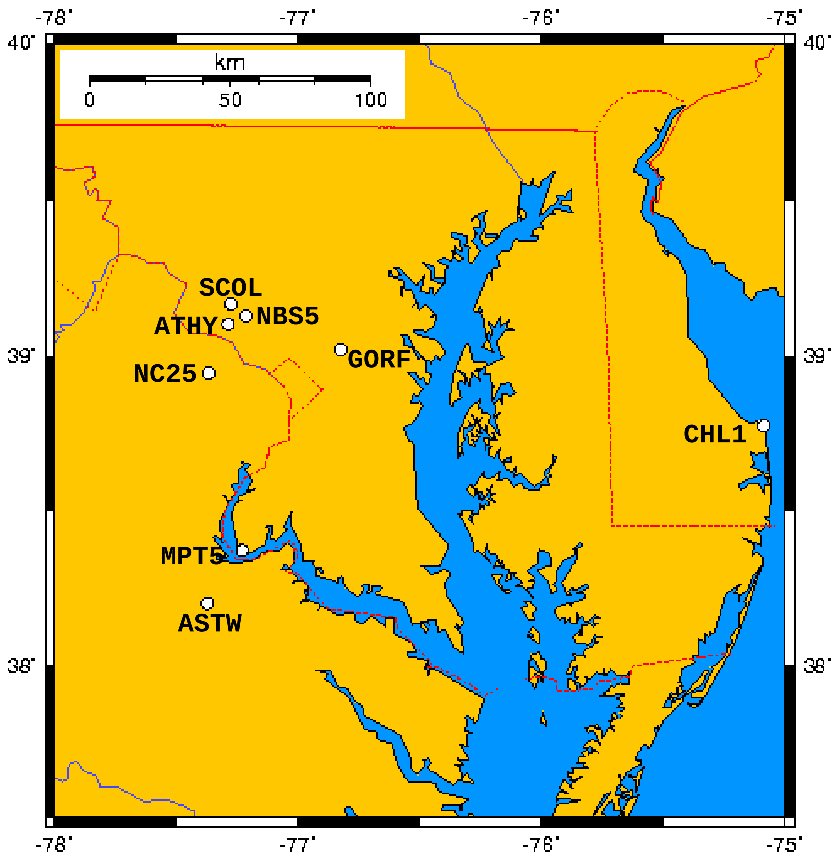


Figure 1. Map showing stations occupied during the FGCS test. Stations GAIT, NBS0, NBS1, NBS3, and ORM1 are all clustered within 2 km of NBS5. The kinematic stations are also clustered near NBS5.

Satellite Visibility

Satellite visibility was good throughout the observing sessions. The number of satellites above 15 degrees and the PDOP for session 320A at station NBS5 are shown in Figure 2. On the same day, a later 3-hour session was also collected using a Trimble 4800 receiver. Figure 2 also shows the satellite visibility for that session which is representative of the session during those hours on day 319 of this test.

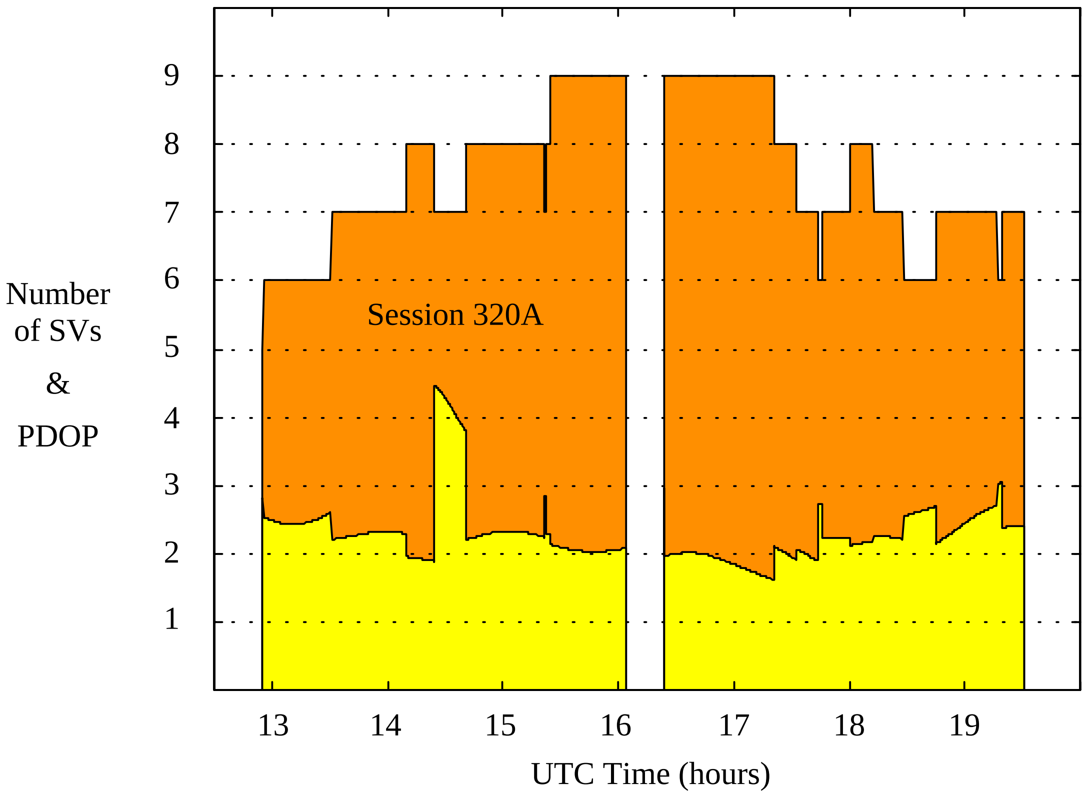


Figure 2. Satellite Visibility for UTC hours 13 through 19.5 on day 320 at station NBS5. Orange region shows number of satellites tracked above 15 degrees, yellow region shows the corresponding PDOP for the satellite constellation.

GPSurvey Postprocessing

The GPSurvey software suite was used to postprocess all baselines from the observations. The data from the CORS stations, in RINEX format, was loaded directly into GPSurvey and processed along with the data from the 4700 receiver. Standard default controls were used in the WAVE processor, which included:

- 15-degree elevation mask
- Elevation-dependent antenna phase center models

- L1-only processing on baselines 5000 meters or shorter
- L1/L2 ionosphere-free processing for baselines longer than 5000 m
- Estimation of zenith delay states for tropospheric modeling on sessions longer than 2 hours
- OTF initialization for kinematic data processing

The default controls also include the use of broadcast orbits. However, IGS rapid orbits were used for processing sessions 320A and 321A.

Data Analysis

Repeat Baselines

For all the sessions observed, a total of 93 baselines were processed. Of those, 51 are repeated baseline observations. For each repeated baseline solution, we arbitrarily chose one solution and differenced all repeated solutions with it. From these differences we report the delta-north, delta-east, and delta-up components, and compare them with the specification. These differences are listed in Table A2 (see Appendix). For the horizontal component, 82% of the repeated baselines are within the one-sigma specification for horizontal accuracy, and 96% are within two-sigma. For the vertical component, 80% of the repeated baselines are within the one-sigma specification and all baselines are within two-sigma.

The mean baseline repeatabilities are listed in Table 5.

Table 5. Mean and Standard Deviation of all 51 repeated baselines.

∆North	∆East	∆Horizontal	∆Up
-0.001 ± 0.007	-0.001 ± 0.005	0.006 ± 0.006	-0.001 ± 0.01

Loop Closures

Loop closures were formed to test of the consistency of the baseline solutions. One closure was formed for the short baselines (Table 6) and one for the long baselines (Table 7). Each closure included station GAIT which was using a different type of antenna – a choke ring. The small closure errors indicate that the baseline solutions are consistent even using mixed antennas.

Table 6. Short baseline loop closures in meters.

FROM	TO	SESSION	∑ LENGTH (m)
ATHY	GAIT	319C	6830
GAIT	NBS1	319E	7487
NBS1	NBS0	319C	7671
NBS0	ORM1	319E	8980
ORM1	NBS3	319C	10091
NBS3	NBS5	319E	10610
NBS5	ATHY	319A	17699
ΔN 0.007	ΔE 0.001	ΔU -0.001	PPM 0.44

Table 7. Long baseline loop closures in meters.

FROM	TO	SESSION	∑ LENGTH (m)
ASTW	NC25	321A	82660
NC25	ATHY	321A	101366
ATHY	GAIT	319A	108197
GAIT	NBS5	319A	108868
NBS5	ORM1	321A	110462
ORM1	GORF	321A	145042
GORF	MPT5	320A	225059
MPT5	ASTW	320A	247772
ΔN 0.007	ΔE -0.007	ΔU -0.012	PPM 0.06

Network Adjustment Coordinate Comparisons

Two network adjustments were performed. The first adjustment included only minimal constraints by fixing coordinates of just one station. The second adjustment constrains the coordinates of three stations. The adjusted coordinates are then compared to the reference coordinates provided by the FGCS.

The FGCS reference coordinates are derived from a minimally constrained adjustment of an "historical" set of over 1200 vectors from past FGCS tests. The station GORF was held fixed in that adjustment to the same values as it was assigned for the NGS adjustment of the Maryland state High Accuracy Reference Network (HARN) in 1993.

Minimally Constrained Adjustment Coordinate Comparisons

The latitude, longitude, and ellipsoid height of the station GORF are held fixed to the reference coordinates provided by the FGCS (see Appendix Table A1). After adjustment, all station coordinates are compared with their FGCS reference coordinates. Coordinate discrepancies that are computed in a local north, east, up frame are listed in Table 8 in meters.

Table 8. Coordinate Comparisons – Minimally Constrained.

STATION	ΔN	ΔE	ΔU
GORF	0.000	0.000	0.000
ASTW	0.023	0.006	0.001
ATHY	-0.002	0.014	0.030
GAIT	-0.001	0.013	0.055*
NBS0	0.005	0.020	0.026
NBS1	-0.007	0.024	0.014
NBS3	-0.005	0.011	0.017
NBS5	0.000	0.016	0.022
NC25	0.008	0.008	0.018
ORM1	0.000	0.015	0.019
SCOL	-0.011	0.019	0.035
MPT5	0.017	0.002	-0.003

Constrained Adjustment Coordinate Comparisons

The latitude, longitude, and ellipsoid height of the stations GORF, ASTW, and ATHY are held fixed to the reference coordinates provided by the FGCS (see Appendix Table A1). After adjustment, all station coordinates are compared with their FGCS reference coordinates. Coordinate discrepancies that are computed in a local north, east, up frame are listed in Table 9 in meters.

Table 9. Coordinate Comparisons – Constrained.

STATION	ΔN	ΔE	ΔU
GORF	0.000	0.000	0.000
ASTW	0.000	0.000	0.000
ATHY	0.000	0.000	0.000
GAIT	0.001	0.003	0.022*
NBS0	0.007	0.010	0.000
NBS1	-0.005	0.015	-0.012
NBS3	-0.003	0.002	-0.010
NBS5	0.002	0.007	-0.004
NC25	0.004	-0.004	-0.012
ORM1	0.003	0.006	-0.006
SCOL	-0.008	0.008	0.002
MPT5	-0.002	-0.002	-0.002

*An 11 cm height adjustment was added to GAIT to bring it into agreement with the historical FGCS reference coordinates. The antenna reference point (ARP) is commonly used to refer to the bottom of the antenna mount and this is the position used for our baseline solutions as per the current NGS data sheet. If the reference coordinates for GAIT were derived instead for the antenna phase center rather than the ARP, a height problem like this would arise. The difference between the ARP and the L1 phase center for the choke ring antenna at GAIT is 11 cm.

Kinematic Analysis

Both postprocessed kinematic and real-time kinematic techniques were used for the FGCS test. RTK techniques were used on a small network of stations on the NIST grounds and postprocessed kinematic techniques were used to occupy a set of stations along the road while driving away from and back to the NIST site.

For the local kinematic tests, the RTK positions are compared with both the FGCS reference coordinates and with postprocessed kinematic solutions. This test demonstrates both the capabilities of the RTK system and the OTF performance of the WAVE processor

RTK Comparisons

For the RTK test, the base receiver was set up over the mark at the station N102. The RTK rover receiver occupied each of the reference stations for approximately 2 minutes each. Comparisons are made between the RTK positions, the PPK positions, and the FGCS reference coordinates. The comparisons are listed in Table 10.

Table 10. RTK and PPK coordinate comparisons in meters.

	RTK - REFERENCE			PPK – REFERENCE			RTK - PPK		
STATION	ΔN	ΔE	ΔU	ΔN	ΔE	ΔU	ΔN	ΔE	ΔU
KINA	-0.001	-0.001	-0.012	-0.006	-0.004	-0.009	0.004	0.003	-0.003
KINB	0.000	0.001	-0.011	-0.004	-0.002	-0.008	0.004	0.002	-0.003
KINC	-0.004	0.001	0.002	-0.007	-0.001	-0.001	0.003	0.001	0.003
KIND	0.003	0.001	0.008	0.000	0.001	0.001	0.003	0.001	0.007
KINE	0.003	-0.001	-0.011	0.003	-0.003	-0.013	0.000	0.002	0.002
KINF	-0.003	-0.001	-0.010	-0.003	-0.003	-0.013	0.001	0.002	0.002

Postprocessed Kinematic Comparisons

The same base receiver, at station N102, was used for the postprocessed kinematic. The roving receiver occupied the stations for 5 minutes. In between stations, the range pole was attached to the back of a vehicle while driving to the next station. At the last station, the vehicle turned around and the procedure was repeated in reverse back to the NIST site. Since no reference coordinates were provided for these stations, the forward and backward runs were compared (Table 11, in meters).

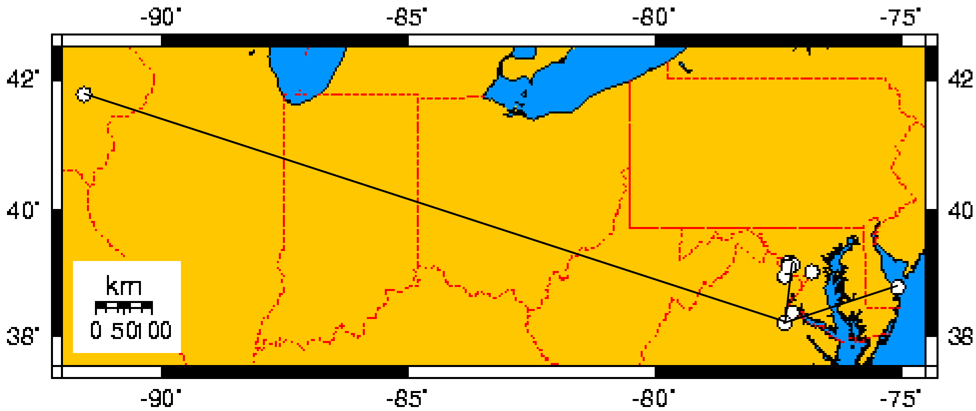
Table 11. Postprocessed kinematic comparison.

STATION	ΔN	ΔE	ΔU
KINA	0.003	0.001	-0.004
SURV	-0.005	-0.016	-0.001
KINM	-0.008	0.002	0.008
STAT	-0.005	0.017	-0.003
RAPI	-0.037	-0.007	0.024

CORS Processing Demonstration

In addition to the static and kinematic testing above, the FGCS also requested a demonstration of the capability to process CORS data from non-Trimble receivers in the RINEX data format. Three stations were chosen – CHL1, GAIT, and NLIB. Since NLIB is located in Iowa, this test also highlighted the very long baseline performance of the WAVE processor.

The strategy was to process these baselines for the session 320A, and make coordinate comparisons to ASTW. IGS rapid orbits were used for this processing. Reference coordinates for the CORS stations were taken from the NGS data sheets retrieved during the week of the test. The antenna reference point (ARP) was used for the ellipsoid heights. The stations and baselines are shown in Figure 3.



To make comparisons, the baseline from GAIT to ASTW was chosen as a reference. Then baseline solutions from NLIB and CHL1 were used to make coordinate comparisons with the reference coordinates derived from the GAIT to ASTW baseline. Fixed integer ambiguity solutions were obtained for all three baselines. The baselines and the coordinate comparisons are listed in Table 12, in meters.

Table 12. CORS processing results and coordinate comparisons at ASTW.

FROM	TO	LENGTH	ΔN	ΔE	ΔU
CHL1	ASTW	209361	-0.005	0.020	0.003
NLIB	ASTW	1272160	0.042	0.009	0.051

Processing RINEX data from the CORS sites is routine in GPSurvey. This comparison shows that over a 1,200 km baseline with only three hours of data, the WAVE processor performs well. While these results are very good, Trimble recommends longer occupation times for these very long baselines.

Acknowledgements

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Appendix

All stations observed during this FGCS test are listed in Table A1. For each station the table shows the Station ID, Station Designation, the NGS PID, and the FGCS reference coordinates.

Table A1. Stations Observed and FGCS Reference Coordinates.

STATION ID	STATION DESIGNATION	FGCS REFERENCE COORDINATES Latitude (DMS), Longitude(DMS), EH (m)	PID
ASTW	ASTRO WEST PIER	38 12 07.39458, -77 22 24.36042, 35.691	HV3124
ATHY	ATHEY	39 06 11.46945, -77 17 21.68697, 104.159	JV2900
GAIT	GAITHERSBURG ARP	39 08 02.34010, -77 13 15.51893, 108.976	AF9522
GORF	NORTH GEOS PIER	39 01 15.40522, -76 49 38.95068, 20.215	JV5895
KINA	KIN A	39 07 53.04756, -77 12 48.66779, 102.995	JV6385
KINB	KIN B	39 07 53.48229, -77 12 49.44924, 103.619	JV6384
KINC	KIN C	39 07 53.47924, -77 12 53.17708, 103.675	JV6383
KIND	KIN D	39 07 53.44264, -77 12 55.65420, 101.867	JV6382
KINE	KIN E	39 07 50.19213, -77 12 48.62389, 100.722	JV6386
KINF	KIN F	39 07 47.02413, -77 12 48.56942, 98.465	JV6387
KINM	KINEMATIC	39 15 54.13524, -77 13 7.05448, 197.292	JV7074
MPT5	MARYLAND PT RM 5	38 22 24.19651, -77 13 53.45517, -24.830	HV8128
N102	NBS 102	39 07 51.97909, -77 12 53.73590, 105.780	JV2194
NBS0	NBS	39 08 07.24135, -77 12 49.01732, 107.968	JV2192
NBS1	NBS 1	39 08 01.30777, -77 12 48.22252, 106.299	JV6388
NBS3	NBS 3	39 07 51.01204, -77 12 32.76989, 105.441	JV6440
NBS5	NBS 5	39 07 48.36850, -77 12 54.11633, 105.583	JV6439
NC25	NC 25	38 56 48.06015, -77 22 9.84069, 91.362	HV9245
ORM1	OBSERVATORY RM 1	39 08 11.60117, -77 11 54.80866, 121.797	JV4124
SCOL	SCHOOL	39 10 13.16864, -77 16 35.84174, 121.605	JV4456
RAPI	RAPID	N/A[1]	JV7073
STAT	STATIC	N/A[1]	JV7072
SURV	SURVEY	N/A[1]	JV7077
NAD83 (CORS) EPOCH 1997.0			
CHL1	CAPE HENLOPEN 1 ARP	38 46 36.40716, -75 05 15.66304, -12.211	AF9492
NLIB	NORTH LIBERTY ARP	41 46 17.70029, -91 34 29.59287, 208.149	AF9523
GAIT	GAITHERSBURG ARP	39 08 02.34060, -77 13 15.51927, 108.937	AF9522

1 N/A: Coordinates not available.

All repeated baselines are listed in Table A2. The table includes the endpoint station ID's of each baseline (From and To), the length of the baseline, the component differences from a reference baseline, for east, north, horizontal, and height, the horizontal and vertical one-sigma specification and the sessions to which each baseline belongs.

Table A2. Repeated Baselines for all sessions.

From	To	Length (m)	∆North (m)	∆East (m)	∆Horizontal (m)	Horizontal Spec. (m)	∆U (m)	Vertical Spec.(m)	Sessions
ASTW	NBS5	103940	0.002	0.000	0.002	0.109	0.003	0.114	320A/321A
ASTW	NC25	82660	-0.001	0.000	0.001	0.088	-0.014	0.093	320A/321A
ATHY	NBS0	7460	-0.009	-0.010	0.013	0.012	0.006	0.017	319A/319C
ATHY	NBS0	7460	-0.018	-0.018	0.025	0.012	0.009	0.017	319A/319E
ATHY	NBS1	7391	-0.005	-0.006	0.008	0.012	0.010	0.017	319A/319C
ATHY	NBS1	7391	-0.012	-0.013	0.018	0.012	0.021	0.017	319A/319E
ATHY	NBS3	7589	-0.005	-0.019	0.020	0.013	0.003	0.018	319A/319C
ATHY	NBS3	7589	-0.011	-0.027	0.029	0.013	-0.002	0.018	319A/319E
ATHY	NBS5	7089	0.007	0.012	0.014	0.012	-0.010	0.017	319E/319C
ATHY	NBS5	7089	0.003	0.006	0.006	0.012	0.004	0.017	319E/319E
ATHY	NBS5	7089	0.013	0.010	0.016	0.012	-0.014	0.017	319E/321A
ATHY	ORM1	8683	-0.003	-0.005	0.006	0.014	0.015	0.019	319A/319C
ATHY	ORM1	8683	0.012	0.002	0.013	0.014	0.002	0.019	319A/321A
ATHY	ORM1	8683	-0.002	-0.010	0.010	0.014	0.021	0.019	319A/319E
GAIT	ATHY	6831	-0.004	-0.007	0.008	0.012	0.009	0.017	319C/319A
GAIT	ATHY	6831	0.003	0.004	0.005	0.012	-0.006	0.017	319C/319E
GAIT	NBS0	654	0.000	-0.005	0.005	0.006	0.011	0.011	319C/319A
GAIT	NBS0	654	-0.003	-0.003	0.004	0.006	-0.010	0.011	319C/319E
GAIT	NBS1	656	-0.004	0.000	0.004	0.006	-0.008	0.011	319A/319E
GAIT	NBS1	656	-0.001	0.001	0.002	0.006	0.000	0.011	319A/319C
GAIT	NBS3	1085	-0.002	0.001	0.002	0.006	-0.014	0.011	319A/319E
GAIT	NBS3	1085	-0.002	0.003	0.003	0.006	-0.004	0.011	319A/319C
GAIT	NBS5	671	-0.001	-0.002	0.002	0.006	-0.007	0.011	319A/319E
GAIT	NBS5	671	-0.001	0.000	0.001	0.006	0.001	0.011	319A/319C
GAIT	ORM1	1959	0.001	0.004	0.004	0.007	-0.011	0.012	319A/319E
GAIT	ORM1	1959	-0.002	0.004	0.004	0.007	0.011	0.012	319A/319C
NBS0	NBS1	184	-0.001	-0.002	0.003	0.005	0.009	0.010	319A/319C
NBS0	NBS1	184	0.000	0.001	0.001	0.005	0.007	0.010	319A/319E
NBS0	NBS3	635	-0.003	-0.001	0.003	0.006	0.002	0.011	319E/319C
NBS0	NBS3	635	-0.002	0.003	0.004	0.006	-0.013	0.011	319E/319A
NBS0	ORM1	1309	-0.001	-0.004	0.004	0.006	0.015	0.011	319E/319C
NBS0	ORM1	1309	-0.002	-0.005	0.006	0.006	-0.006	0.011	319E/319A
NBS1	NBS3	488	-0.002	0.000	0.002	0.005	-0.002	0.010	319C/319A
NBS1	NBS3	488	0.003	-0.001	0.003	0.005	-0.003	0.010	319C/319E

Table A2. Repeated Baselines for all sessions – continued.

From	To	Length (m)	ΔNorth (m)	ΔEast (m)	ΔHorizontal (m)	Horizontal Spec. (m)	ΔU (m)	Vertical Spec.(m)	Sessions
NBS1	ORM1	1322	-0.001	-0.002	0.002	0.006	-0.013	0.011	319C/319A
NBS1	ORM1	1322	0.001	0.001	0.001	0.006	-0.016	0.011	319C/319E
NBS3	ORM1	1111	0.003	0.000	0.003	0.006	0.000	0.011	319C/319A
NBS3	ORM1	1111	0.000	0.001	0.001	0.006	-0.010	0.011	319C/319E
NBS5	NBS0	595	0.001	0.004	0.004	0.006	-0.011	0.011	319A/319C
NBS5	NBS0	595	-0.003	0.003	0.004	0.006	-0.013	0.011	319A/319E
NBS5	NBS1	423	0.000	0.001	0.001	0.005	-0.001	0.010	319A/319C
NBS5	NBS1	423	-0.004	0.003	0.005	0.005	-0.003	0.010	319A/319E
NBS5	NBS3	519	0.002	0.000	0.002	0.006	-0.002	0.011	319A/319C
NBS5	NBS3	519	0.002	0.000	0.002	0.006	-0.005	0.011	319A/319E
NBS5	NC25	24357	-0.003	0.001	0.003	0.029	-0.029	0.034	320A/321A
NBS5	ORM1	1595	0.000	0.003	0.003	0.007	0.008	0.012	319A/319C
NBS5	ORM1	1595	0.007	0.006	0.009	0.007	0.007	0.012	319A/321A
NBS5	ORM1	1595	0.000	0.004	0.004	0.007	-0.007	0.012	319A/319E
GORF	ASTW	102588	-0.001	-0.002	0.002	0.108	0.012	0.113	320A/321A
GORF	NBS5	35659	0.002	-0.002	0.002	0.041	0.010	0.046	320A/321A
GORF	NC25	47673	-0.001	-0.001	0.002	0.053	-0.012	0.058	320A/321A

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